

segments. The latter value is different from that for the supercell case because the underlying radio architecture used for the investment inputs is different.

Based on the amount of spectrum, the market size and the penetration and subscriber service parameters, the model determines the required capacity for the network in the tenth year. Based on projected capacity demand the model automatically chooses to build either a supercell or multicell network. This selection process is perhaps the single most important function in the model, for it is the type of network, and attendant number of cell sites and resulting radios and backhaul, that drives investment and operating expenses. Even for large markets that would immediately require a multicell network, a reduction in the available amount of spectrum can significantly increase costs as the only way to make up for a lack of spectral capacity is to compensate with more cell sites.

If the most capacity-rich of the three supercell configurations cannot support the projected demand, a multicell network is selected and priced. Once again, the amount of spectrum available is taken into account and the multicell network is designed to provide enough capacity to meet 10th year subscriber capacity.²¹ For either type of network, cell sites are populated with incremental radio channels only as subscriber numbers and demand rises over the study period.

also have been selected for modeling purposes. We chose the former design because corresponding budgetary equipment prices were available for use in our business case model development.

²¹ As explained in the technical section of this study there is a limit on how close cells can be placed, which – coupled with a finite amount of spectrum – could theoretically limit the capacity available in the densest part of the very largest markets. However, given adequate spectrum, capacity limitations should be few.

Backhaul

Backhaul and transport requirements and expenses are generated for the network as designed by the model. For smaller markets in which leased DS-3s are not likely to be available, the model equips dedicated microwave backhaul systems per cell at \$125,000 initially for a DS-3 system per site and \$25,000 per additional DS-3 radio, which the model equips as required by local demand. For larger markets in which DS-3s are likely to be available from the ILEC or other carriers, the model assumes a monthly lease of \$3,000 per DS-3. As in the supercell case, there is an assumed leased connection between the ILEC (or other service provider) and the ISP of \$20,000 per OC-3 per month.

Subscriber Acquisition

The cost of subscriber acquisition is incorporated into the model by including the cost of providing CPE, installing the equipment, and sales and marketing. The CPE and installation costs trend down over time as the equipment gets less expensive due to production and volume efficiencies, and installation processes get more refined and faster. Table V-5 outlines the values used in subscriber acquisition calculations.

Table V-5: HMI Model Subscriber Acquisition Parameters

Service	Beginning CPE Cost	10th Year CPE Cost	Beginning Installation Cost	10th Year Installation Cost	Sales & Marketing Cost Per Sub	Installation Revenue Per Subscriber
Residential	\$700	\$350	\$350	\$200	\$250	\$ 99.95
Commercial	\$700	\$350	\$500	\$300	\$500	\$199.95

The CPE for both residential and commercial subscribers is expected to be the same. However the installation in a commercial environment is expected to be more

complex, and the cost of marketing to commercial subscribers more targeted, and therefore more expensive (less mass media marketing, more direct sales calls, etc.).

General and Administrative

Finally, the model adds a number of general and administrative (“G&A”) expenses to come to a final net cash flow calculation for the sample market. The G&A expenses include a monthly expense per subscriber for billing and customer service, and a general gross up of all other expenses for overhead. Also, over time subscriber pricing erodes (5 percent a year), as does the cost of leased bandwidth (10 percent a year), while all other expenses rise slightly each year (3 percent a year).

C. HMI Model Results

The model very clearly demonstrates that if spectrum for an MMDS/ITFS network is reduced there is a direct, virtually linear, effect on capital requirements and operating expenses and a negative effect on the attractiveness of the business opportunity. The following tables and charts summarize the findings.

Table V-6 provides an overview of the impact on network type and cell site requirements for the two spectrum scenarios (26 channels and a reduction to 11 channels) for the sample market in each quintile.

Table V-6: Spectrum Reduction and the Change in Network Technology Requirements and Cell Site Counts

Quintile	Network Type		Number of Cell Sites In Year 10 ²²	
	26 Channels	11 Channels	26 Channels	11 Channels
1	MultiCell	MultiCell	42	113
2	MultiCell	MultiCell	13	35
3	SuperCell	MultiCell	1	22
4	SuperCell	MultiCell	1	15
5	SuperCell	SuperCell	1	1

Note that with the exception of the very smallest sample market in quintile 5, all markets must go to a multicell network if they are to have enough capacity to meet subscriber targets using only 11 channels. For the larger markets the reduction in spectrum increases the number of cell sites by a factor of 2.7. Overall, the reaction to a reduction in spectrum is a huge increase in required capital that extends across all quintiles, as demonstrated in Table V-7.

Table V-7: Spectrum Reduction and the Change In Estimated Capital Investment²³

Quintile	Network Investment By End of 10 th Year (\$ Millions)		Investment Per 10 th Year Subscriber	
	26 Channels	11 Channels	26 Channels	11 Channels
1	\$ 35.5	\$ 90.9	\$ 994	\$ 2,479
2	\$ 11.6	\$ 51.3	\$ 1,026	\$ 2,498
3	\$ 3.4	\$ 20.7	\$ 479	\$2,928
4	\$ 2.2	\$ 14.2	\$ 461	\$2,993
5	\$ 1.4	\$ 2.4	\$ 480	\$ 810

The increase in investment requirements, as should be expected, follows very closely with the proliferation of required cell sites. Even for the sole quintile that remains

²² A supercell market has by definition only one cell site. For a multicell network the model builds sites as needed for projected capacity. For instance, in the quintile one market given 26 channels, the number of cell sites needed to meet projected first year demand is only five.

²³ The capital investment includes all cell site hardware such as antennae, radios and network electronics, as well as all required backhaul microwave systems. Actual cell sites (tower or rooftop space and network equipment space) are rented and considered an operating expense.

supercell, quintile 5, capital costs increase dramatically as a more expensive type of supercell is required.

Another important point developed in Table V-7 is the economic efficiency of being able to operate with a supercell, making it a viable technology for small markets and low-density areas. Note the relatively low per-subscriber investment for 26-channel operation in quintiles 3, 4 and 5.²⁴

Most operators are in multiple markets. Assuming 50 markets in each quintile, with each market roughly the same size as the median market used for the sample, the total capital requirement for the industry would increase to \$8.975 billion from \$2.705 billion if the number of available channels were reduced by 15 (90 MHz).²⁵ This more than threefold expansion is especially daunting considering the current difficulty that new technology firms are having in attracting capital.

The increased capital expenditures do not generate a positive financial return. In fact, this additional capital is necessary to provide the same amount of subscriber capacity, services, and revenue as could otherwise be provided for less investment with 26 channels. As a consequence, overall returns deteriorate significantly. This makes it unrealistic to expect that an MMDS/ITFS carrier can justify any increased capital investment to the financial markets.

The proliferation of cell sites also causes increased operating expenses. Direct operating costs such as backhaul costs, network maintenance, site rent, and site utilities

²⁴ Investment inputs for multicell technology used in the model are based on predicted costs and price reduction curves for technology that is not fully developed and are fairly conservative. It may well be that the multicell technology will drop in price much more rapidly and significantly than projected, but that would equally benefit both spectrum scenarios.

all increase in direct relation to the number of cell sites. Table V-8 demonstrates the effect of spectrum reduction on operating expenses.

Table V-8: Spectrum Reduction and the Change In Estimated Operating Expenses

Quintile	Cumulative Operating Expenses By End of the 10 th Year (\$ Millions)		Average Annual Operating Expenses Per Subscriber Over 10 Years	
	26 Channels	11 Channels	26 Channels	11 Channels
1	\$ 43.3	\$ 74.9	\$ 236	\$ 388
2	\$ 14.8	\$ 23.9	\$ 293	\$ 418
3	\$ 7.4	\$ 13.8	\$ 271	\$ 403
4	\$ 6.3	\$ 9.8	\$ 366	\$ 458
5	\$ 5.3	\$ 6.5	\$ 532	\$ 587

Operating expenses show a significant negative performance (though less dramatic than capital requirements) with a reduction in spectrum.²⁶ The more complex network of cell sites required to offset spectrum reduction leads to more backhaul links to lease, more sites to rent, and more radios. All of this requires more technicians, trucks and tools.²⁷

In order to tie together and demonstrate the total effect of increased capital requirements and operating expenses, the HMI Model calculates an internal rate of return (“IRR”). IRR is commonly used to compare the relative attractiveness of two opportunities with different cost and revenue streams. Also, companies often use IRR in making “go-no-go” decisions on an opportunity. In this study, IRR is used primarily to

²⁵ Note that this increase in capital only covers incremental network investment to compensate for reduced spectrum, not any increased operating costs that must be covered prior to reaching positive cash flow.

²⁶ The larger markets, whether using supercell or multicell technology, achieve more efficient operation than the smaller markets with less population. This is reflected in the better expense per subscriber figures and shallower increase in expenses as market size rises.

²⁷ Although subscriber levels, and therefore the overall cost of subscriber acquisition, billing and care stays constant, there is also a slight change in other G&A expenses between the two spectrum scenarios. The greater operating expenses caused by the need for, among other elements, more technicians, trucks, etc. would cause an increase in G&A expenses such as human resources, payroll and accounting.

compare the overall effect of reducing spectrum in a given market on the economics and business viability for an MMDS/ITFS carrier in *that given market*.²⁸

The IRR calculation is based on a “cash on cash” revenue stream. A net cash flow stream of annual revenues minus expenses and investment is determined. Also included in the calculation of the IRR is a terminal value to reflect the ongoing worth of the enterprise beyond the 10th year of the study period. For businesses that generate recurring revenue, the value of the enterprise is often expressed as a multiple of net cash flow. In this model, a conservative exit multiple of 8 times 10th year operating cash flow (before investment expenses) is calculated and added to the revenue for year 10.²⁹

Table V-9: Spectrum Reduction and the Change In Internal Rate of Return

Quintile	Estimated IRR Over 10 Years	
	26 Channels	11 Channels
1	18.55%	Less Than 0%
2	13.05%	Less Than 0%
3	24.02%	Less Than 0%
4	19.68%	Less Than 0%
5	11.55%	Less Than 0%

The IRR summary plainly shows that, no matter the market size, reducing spectrum by 90 MHz for an MMDS/ITFS carrier would effectively eliminate them as a

²⁸ The IRRs generated by the HMI Model are very accurate in reflecting the effect of changes such as spectrum reductions on the MMDS/ITFS business proposition, and are generally also representative of the overall MMDS/ITFS business cases. However, the specific purpose of this study is to show the effect of fundamental market changes, not to make an investment decision. The important consideration is the change in IRR for the *same* sample markets, not across markets of differing size. The model cannot be specifically tailored for every unique market and specific cost change.

²⁹ An alternative means of calculating IRR would be to use the annual cost of financing capital investment instead of the actual cost of capital investment incurred each year. This effectively spreads out the cost of investment over the term of the study, rather than front-loading it into the early years where much of the capital expenditure occurs. The net effect would be an estimated increase of 3 percent-5 percent in IRR for each sample market return, under each spectrum scenario. Again, the important aspect of IRR in the context of this study is the degree of change within the same sample market given the change in available spectrum. The precise means of calculating IRR is relatively immaterial as long as it is done in a consistent manner.

market competitor.³⁰ Essentially, even after ten years of operation and accounting for the value of the operation, no market can viably operate with only 11 channels.

VI. Conclusion

The inescapable conclusion is that any marked reduction in usable spectrum would eliminate MMDS/ITFS carriers from the broadband access market. The business model constructed here demonstrates that successful deployment of the service requires the use of all of the spectrum that is currently available. Reductions in spectrum availability, as proposed by the FCC, would require more expensive network configurations or reduce the size of the addressable market.

³⁰ The corollary response to spectrum reduction, which would be to keep network investment constant but effectively reduce subscriber capacity, would produce an IRR table with similar results. Clearly, reducing subscribers reduces revenue, which would then fail to cover capital investment and operating expenses – producing a negligible return on investment.

ATTACHMENT 1

HAI Consulting, Inc.

HAI Consulting, Inc. (formerly Hatfield Associates, Inc.) is an interdisciplinary consulting and research firm serving a wide range of clients with stakes in the telecommunications field. Hatfield Associates was founded in February 1982. With the departure of Dale Hatfield to the FCC in 1997, the remaining associates formed HAI Consulting, Inc. HAI and Hatfield Associates have provided consulting and educational services in nearly all aspects of the present and future telecommunications infrastructure, including local exchange networks, cable television systems, competitive access networks, land mobile and personal communications, long haul terrestrial and satellite communications, data communications, and customer premises equipment.

The firm has substantive experience in telecommunications cost modeling. Enduring Local Bottleneck I (with ETI) and Enduring Local Bottleneck II provided business case models designed to investigate the attractiveness of wireless and cable entry into local telephone markets.

The firm also has extensive experience in wireless competition and spectrum issues. The firm has assisted a number of clients in FCC spectrum auctions. Wireless market structure and competition issues have been analyzed in several papers presented in various FCC dockets.

Principal Contributors

Gene G. Ax Senior Communications Engineer

Gene G. Ax is a senior communications engineer with HAI Consulting, Inc. (formerly Hatfield Associates, Inc.); he has been with the firm since September 1982 except for the period between September 1985 and December 1987. Mr. Ax has over 30 years experience as a communications engineer. At HAI he has been involved in a series of studies and engineering applications in the cellular, Personal Communications Services (PCS), mobile radio, specialized mobile radio, telephone systems, spectrum management, satellite, cable television, and microwave radio fields. His primary duties include technological research and analysis for all types of telecommunications services/systems, including engineering analysis of regulatory constraints.

He has studied short-haul microwave systems for interconnecting with fiber optic and microwave long-haul systems as well as for interconnecting with hub earth stations associated with very small aperture terminals (VSATs) that communicate through one or more communications satellites and one or more earth station hubs. Mr. Ax also participated in VSAT satellite communications system studies. Further studies were performed concerning networked, large coverage (metropolitan to nationwide for the U.S.) land mobile radio systems, primarily for mobile but for fixed applications as well. Mr. Ax participated in the development of a computer-based network design and management tool for networked, land mobile systems with strong contributions to RF

engineering needs with special emphasis on RF coverage, including many cellular configurations.

Mr. Ax received B.S. and M.S. degrees in electrical engineering from the Universities of Idaho and Colorado respectively. Further graduate studies were pursued at the University of Colorado and a year of full-time graduate study followed at the University of California at Berkeley, all in electrical engineering.

Alan J. Boyer
Senior Consultant

Joe Boyer assists clients who are developing telecommunications businesses with a particular focus on wireless telecom opportunities. He has extensive experience in analyzing, valuing, acquiring and operating wireless telecom businesses - including integrated microwave networks, LMDS, PCS, SMR, paging and cellular properties. Clients have access to a broad-based expertise that has been drawn upon for early stage business planning; special projects related to acquisitions or spectrum auctions; spectrum management or valuation issues; or a short-term operational management need.

Among other significant assignments, Mr. Boyer has created an economic model to demonstrate the cost of employing mobile wireless technology for fixed access (wireless local loop) applications. This model is being used to contrast wireless costs to wireline costs in several regulatory forums.

Another recent project was a study of the potential for competition in the domestic local exchange carrier market on behalf of a major international telecommunications carrier. This study approached the topic from a real world basis and focused on the potential competitiveness of wireless local loop and cable telephony. Mr. Boyer focused principally on the wireless aspects of the study, in which availability of radio spectrum, technology, financing and the regulatory climate were all analyzed and incorporated into the findings.

Other recent activities have included strategic planning and auction management for clients in several FCC auctions, the analysis and valuation of the spectrum held by several major SMR consolidators; a critical analysis of the potential of LMDS (Local Multipoint Distribution Service) as a broadband local access technology; research on

potential radio spectrum availability and transmitter site requirements; and an analysis of telecommunications technologies impacting future services for public broadcasting.

Prior to joining HAI in early 1996, Mr. Boyer spent nine years on the senior management team of the Telecommunications & Technology Group of Fidelity Capital, a wholly owned subsidiary of Fidelity Investments. This group was charged with identifying telecommunications opportunities and creating business units to pursue them. As a Senior Project Manager within the relatively small group he was directly responsible for a range of strategic planning and business development, operations and technical planning, and regulatory affairs functions.

Mr. Boyer earned a BA, with Honors, in Business Administration from the California State University - San Francisco with an emphasis in International Finance. He also successfully completed course work towards an MS in Telecommunications at the University of Colorado, Boulder.

Richard A. Chandler
Senior Vice President

Richard A. Chandler is a senior vice president with HAI Consulting, Inc., where he performs a range of consulting services for clients, including evaluation of various communication technologies to address specific user requirements, review of large corporate network structures and operations, as well as the evaluation of the suitability of new products for particular markets. Among other assignments as a consultant, he has developed the technical plan for a proposed wireless-based telecommunications system to provide basic internal telephone service as well as international connectivity to the populace of a developing nation. He has worked with a Korean international carrier in the development of the technical and operating plan for a proposed Korean PCS network. Other contracts have involved the development of regional and nationwide architectures for mobile data networks and evaluation of voice compression and automated conferencing systems to support both internal and external investment decisions. He has worked extensively in the wireless communication area, studying Personal Communications Network architectural issues, including radio segment structures, backhaul networks, and interconnection issues for several clients. Most recently, Mr. Chandler has developed sophisticated telecommunications network models for use in determining the costs of telephone service, including local and toll; he has been the principal developer of the Hatfield and HAI Models commissioned by MCI WorldCom and AT&T Corp. for use at the state and national levels in supporting interconnection and universal service filings. He has also written numerous affidavits and declarations dealing with various telecommunications technologies in several regulatory and court proceedings.

Before joining Hatfield Associates (now HAI Consulting, Inc.) in 1986, Mr. Chandler joined Skylink Corporation as Vice President - Network Engineering. While at Skylink, Mr. Chandler developed the ground system control and switching architecture and user terminal requirements for the proposed Skylink network. He developed a distributed control structure, which allowed for the decentralization of system intelligence, enabling the simultaneous operation of multiple independent subnetworks. He also developed a packet switching mechanism for the network, which enables hundreds of interactive users to share a single radio channel for data transmission. He worked jointly with mobile radio and satellite earth station manufacturers to develop preliminary ground terminal and user terminal functional requirements and technical specifications.

Mr. Chandler joined the AT&T marketing organization in 1981, where he initially was a product manager for data switching and adjunct processor enhancements for existing PBX products. In this capacity, he was responsible for coordinating design, development, and manufacturing efforts, developing business case inputs for product pricing, and coordinating training and advertising for the new products. In another assignment within this organization, he developed product strategies for advanced data switching technologies, including adjunct packet switches for customer data. He also headed a group furnishing technical support regarding product architecture and features to the AT&T field sales force and providing customer requirements to the development and product management organizations.

In 1977, Mr. Chandler joined Bell Telephone Laboratories, where he participated in exploratory studies of new PBX systems for AT&T. These investigations included the

review of various switching system architectures and control structures for next-generation private branch exchanges. He designed and developed segments of a laboratory model of a new PBX and coordinated designs and interfaces for the production version of the new machine. He also studied design approaches and circuit modifications to enhance the reliability of new switching systems. In another significant assignment, he worked on packet switching techniques to be applied to a multi-processor control structure, and he participated in the development of specific packet switch designs to be applied as an adjunct to the circuit-switched network fabric for the purpose of switching user terminal-to-host and host-to-host data traffic.

From 1972 to 1977, Mr. Chandler was an electronic engineer with the Institute for Telecommunication Sciences, a telecommunications research organization within the U.S. Department of Commerce. While at ITS, he performed microwave propagation studies for atmospheric paths in the 60 GHz region, and he developed experiments for studies of space-to-earth paths at 20 GHz and 30 GHz. He also designed experiments and associated instrumentation for availability studies of short atmospheric optical paths in the near infrared. In addition, he participated in and co-authored an extensive review of existing and future cable television technology. He managed a project for the U. S. Department of Transportation for the evaluation of the applicability of tracking radar techniques to vehicular braking systems, and he managed a consulting contract with the National Oceanic and Atmospheric Administration for the technical evaluation of various commercial microwave positioning systems used in hydrographic surveying.

Mr. Chandler received B.S. and M.S. degrees in electrical engineering from the University of Missouri and an M.B.A. from the University of Denver. He pursued

additional graduate work in electrical engineering at the University of Colorado. He serves as an adjunct faculty member at the University of Colorado and the University of Denver and teaches graduate-level courses in telecommunications technology, including wireless and cellular communications and digital switching and transmission.

ATTACHMENT 2



California Amplifier

January 15, 2001

Joe Boyer
HAI Consulting
737 29th Street #200
Boulder, CO 80303

Dear Mr. Boyer,

This letter is written to provide California Amplifier's assessment of the impact of moving MMDS services to frequencies above 3 GHz. California Amplifier is a leading supplier of MMDS customer premise equipment used for the deployment of high-speed data and voice services.

Radio equipment used in contemporary MMDS two-way data systems typically uses technology and components adapted from similar equipment originally designed for use in PCS systems. Product implementations consist of silicon-based integrated circuits and ceramic filter technology, which afford high device densities resulting in compact size and low equipment manufacturing costs. Today's silicon RF and cost-effective ceramic filter technology, however, cannot be used at frequencies greater than about 3 GHz and is effectively stretched to the limits of its capabilities at the MMDS frequencies of 2500-2690 MHz.

If the MMDS/ITFS services were to be reassigned to frequencies above 3 GHz, all existing equipment would need to be redesigned. This would entail using more costly implementations using gallium arsenide (GaAs) circuits and cavity filters. The cost of development, the fact that these implementations at higher frequencies will not support the same level of integration, and the cost of components, is expected to lead to profoundly increased costs for the higher-frequency equipment. Furthermore, at least 24 months would be required to accommodate redesign, testing, and manufacturing of MMDS equipment for use in a new frequency band.

Therefore, we believe that moving MMDS services to frequencies above 3 GHz would increase equipment cost and would cause substantial delay to the deployment of MMDS services.

Please feel free to contact me if you have any questions or require further information.

Sincerely,



Kris Kelkar
Vice President, Wireless Access Products

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